AMENDMENT TO THE TITLE

Please amend the title to read as follows:

SEMICONDUCTOR DEVICE WITH NITROGEN IN OXIDE FILM ON SEMICONDUCTOR SUBSTRATE AND METHOD OF MANUFACTURING THE SAME ~~SEMICONDUCTOR DEVICE~~

AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph beginning at page 4, line 21, with the following rewritten paragraph:

Moreover, this redistribution does not only occur ~~only~~ during the above-mentioned formation of poly-silicon film, but it is also under the influence of all the thermal treatment processes that are performed as later processes. FIG. 3 shows the results of the measurement in which the amount of nitrogen in the vicinity of the interface between the gate oxide film and the semiconductor substrate was measured after each of various thermal treatment process steps was carried out. Among the items shown as the names of thermal treatment process steps in FIG. 3, "IMMEDIATELY AFTER FILM DEPOSITION" indicates the state prior to the poly-silicon film deposition, and "POLYSILICON" indicates the state subsequent to the poly-silicon film deposition. "OXIDATION" indicates the state after side walls have been formed on the gate electrode composed of poly-silicon. "NITRIDE FILM DEPOSITION" and "OXIDE FILM DEPOSITION" indicate the states after a nitride film and [[a]] an oxide film have been formed, respectively, as interlayer insulating films, and "ANNEALING A" and "ANNEALING B" indicate annealing steps for densifying films after depositing the interlayer insulating films, respectively. From FIG. 3, it is understood that the amount of nitrogen increases also due to the various thermal treatment processes that are performed after the poly-silicon film deposition. In addition, some of the process steps did not show the increases, and when attention was directed to process conditions of each of the thermal treatment processes, it was found that the increases did not occur in cases where the temperature is lower than the maximum temperature of the thermal treatment processes that had been performed before. In other words, it can be said that

the final distribution of nitrogen in the gate oxide film is determined by the maximum temperature of all the thermal treatment processes, although in varying degrees. This fact suggests that even if the initial nitrogen distribution is formed ideally using activated nitrogen, there is a possibility that the distribution may be degraded by a later thermal treatment process. It also indicates that the problem arises that, because of fluctuating of nitrogen concentration which greatly affects transistor characteristics, it is difficult to control transistor characteristics.

Please replace the paragraph beginning at page 16, line 15, with the following rewritten paragraph:

(Embodiment 1) FIG. 5 explains the method of manufacturing a semiconductor device in accordance with a first embodiment of the present invention along the order of the process flow. It should be noted that although the present invention is in reality used as part of the manufacturing steps for fabricating various devices typically represented by transistors, not the entire flow for fabricating devices is depicted herein, but only the portions that represent contents, objectives, advantageous effects, and features of the present invention <u>which</u> are extracted therefrom.

Please replace the paragraph beginning at page 22, line 26, with the following rewritten paragraph:

From the line (A), it is understood that variation is remarkably suppressed in comparison with the result of the conventional example (C), in which [[an]] <u>a</u> thermally oxidizing process is not performed as one step of the insulating film formation steps. Of course, the diffusion of nitrogen into the interface is temporarily promoted due to the thermally oxidizing process, as described above (FIG. 6), but the amount of nitrogen in the interface when the device is ultimately finished is clearly smaller in the case of the present invention. This means that when the same thermal treatment process as a whole is carried out, excessive nitrogen is more unlikely to be eliminated and is rather likely to move to the interface in the case where an upper portion of the insulating film is capped by a polysilicon film or the like, and it can be said that the advantageous effects of the present invention are exhibited particularly in cases where a thermal

treatment process is performed without forming a cap layer on the surface. In addition, what is more remarkable is the concentration of nitrogen within a polysilicon electrode (B), and it is understood that in the present invention, it was reduced to the detection limit of the analysis. This seems to be due to the fact that, by performing a re-oxidation process at the maximum temperature while forming an insulating film according to the present invention, it has been made possible to redistribute and eliminate ~~instable~~ unstable excessive nitrogen in advance, and to suppress re-migration and re-distribution during later process steps.

Please replace the paragraph beginning at page 23, line 27, with the following rewritten paragraph:

In addition, the atmosphere during the thermally oxidizing process in FIG. 5(d) is also important, and it is one of the features of the present invention. Specifically, an increase in film thickness due to the thermal treatment process in an atmosphere containing oxygen needs to be suppressed as small as possible, and for that reason, it is necessary to restrict the content of oxygen. FIG. 8 shows a state of increase in film thickness during the thermally oxidizing process, which shows its dependency on the oxygen/nitrogen ratio in cases where a gas flow rate is controlled and varied for the atmosphere. Here, assuming a case in which the final film thickness of the gate oxide film is 20 Å or less, the initial oxide film thickness (FIG. 5(b)) is about 15 Å, and an increase of about 5 Å is permissible. Accordingly, the oxygen/nitrogen flow rate ratio is required to be about 50% or less in this case. It is of course possible that the oxide film thickness is made as thin as, for example, 10 Å, and in that case, a film thickness increase due to the re-oxidation is further permissible; but in reality, it is undesirable in terms of transistor characteristics because the amount of nitrogen reaching the silicon substrate/insulating film interface due to a nitridation process, which is a subsequent step, increases in proportion to the decrease in the thickness of the oxide film, which is the underlayer. On the other hand, it is seen from FIG. 8 that if the flow rate ratio is lower than 0.015%, the amount of film thickness increase becomes 0 or less. This indicates that the film thickness of the insulating film immediately after the nitridation is reduced, which means that the oxide film is partially peeled off in micro regions. Generally, silicon and oxygen occasionally sublimate because of a thermal treatment

process, and when oxygen becomes less than a certain amount, they are eliminated from the inside of the insulating film (surface) in the form of Si-O bonds. When the elimination occurs and proceeds, the insulation performance of the oxide film degrades. It is considered that this phenomenon occurs in the range at or below 0.015% in FIG. 8, and it is very important to realize the ~~atmosphere~~ atmospheric composition above that range.

Please replace the paragraph beginning at page 25, line 13, with the following rewritten paragraph:

Further, this series of ~~phenomenon~~ phenomena will be more readily understood if expressed in the form of partial pressure of oxygen. Here, the partial pressure of oxygen means a pressure in the case where it is assumed that a gas containing oxygen fills up an entire apparatus. The thermally oxidizing process affects not only [[on]] the oxygen gas ratio but also [[on]] the pressure. When the total pressure is set low, the oxygen partial pressure inevitably becomes low, and accordingly, the flow rate of oxygen gas needs to be set high. As a result of various experiments including the above-described conditions, it was discovered that it is important to make the oxygen partial pressure from 0.075 to 250 Torr ~~in terms of suppressing~~ to suppress film thickness increases and ~~preventing~~ prevent sublimation. Compliance with this is important in the present invention.

Please replace the paragraph beginning at page 29, line 19, with the following rewritten paragraph:

Further, one embodiment of the present invention is described with reference to FIG. 11. FIG. 11 is a flowchart representing a fourth embodiment of the present invention, which shows that the processes (A) enclosed by the inner dotted line represent an implementing method of the first and second embodiments while the processes (B) enclosed by the outer dotted line represent an implementing method of the third embodiment. Here, the oxidation for forming an oxide film is denoted by "FIRST OXIDATION", and the thermally oxidizing process after nitrogen has been introduced is denoted by "THERMALLY OXIDIZING". As seen from the flowchart, these steps are carried out in the same chamber, or substrate transfer is performed alternately through a

transport chamber that is isolated from the ambient air so that each of the steps advances without exposing the semiconductor substrate to the ambient air. FIG. 12 represents an example in which processes are configured combining single wafer-type thermal treatment process apparatuses for realizing the flow (A) of FIG. 11, showing the flow of a silicon substrate. Here, a case is shown in which formation of an oxide film, a subsequent nitridation process, and a further subsequent second thermally oxidizing process are achieved in separate chambers. As shown in FIG. 12, first, a substrate is introduced into a load lock chamber 21, and after producing a vacuum in the load lock chamber 21, an oxide film is formed on the substrate in an oxidation chamber 22. Next, after the substrate is transferred through a transport chamber 25, nitrogen is introduced into the oxide film in a plasma nitridation chamber 23. Thereafter, after the substrate is transferred through the transport chamber 25, [[an]] a thermally oxidizing process is carried out in [[an]] a thermally oxidizing process chamber 24. In order to illustrate the effect of the invention, FIG. 13 shows a comparison between the measurement result of the amount of nitrogen immediately before the second thermally oxidizing process and that of the conventional example. The amount of variation over time is smaller when the present invention is adopted (b) than when the silicon substrate is exposed to the ambient air between the nitridation process and the second thermally oxidizing process (a). Although the cause is not clear, it is considered that when the substrate was exposed to the ambient air, such a phenomenon occurred that ~~instable~~ unstable nitrogen immediately after the nitridation is eliminated or migrated due to the environment in the ambient air, whereas by controlling the atmosphere, the variation was suppressed. Since controlling the migration of instable nitrogen is important in controlling transistor characteristics, it is understood that the present invention is very important.

Please replace the paragraph beginning at page 33, line 10, with the following rewritten paragraph:

Furthermore, the embodiments consistently described examples using a silicon substrate as the semiconductor substrate, but the advantageous effects of the present invention [[do]] are not ~~reduce~~ reduced even if germanium, SiC, polysilicon, or the like [[is]] are employed as other substrates. In addition, although an oxide film was shown as an example of the gate oxide film,

it is a matter of course that the invention is applicable to other semiconductor devices in which their characteristics can be improved by reducing the interface states.

Please replace the paragraph beginning at page 33, line 20, with the following rewritten paragraph:

Additionally, regarding FIG. 12, which illustrated the processes ~~are~~ carried out without exposing the substrate to the ambient air, the advantageous effects of the present invention are not lost and similar effects are achieved even if, for example, the oxide film deposition and the thermally oxidizing process are performed within the same chamber but only the nitridation is carried out in a separate chamber, insofar as the combination falls within the present invention, in which the substrate is not exposed to the ambient air, as can be inferred from the fact that the wafer flow shown in the figure is not the only choice but the processes can be implemented within the same chamber.